“Neoker Single Crystal Alumina Fibers as reinforcement in Al-based MMC’s: first steps”

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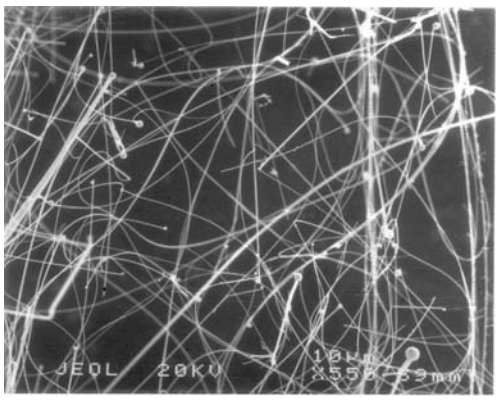
INTRODUCTION

α-Al_2O_3 whiskers are good candidates for use as strengtheners in advanced composites, specifically, single crystal α-Al_2O_3 whiskers grown with ***c***-axis orientation, because of their favorable fracture strength, stiffness, and creep resistance, even at high temperatures are optimum reinforces.

Very few methods are currently available to obtain single-crystal α-Al_2O_3 whiskers, and these methods were too complex and expensive for use on an industrial scale. A novel method for obtaining c-axis alumina single-crystal whiskers (developed at the Institute of Ceramic Materials of Galicia) has been scaled-up to industrial production by **Neoker**, a Spin-Off of the of the University of Santiago de Compostela, Spain. The technology for the production of the whiskers involves the reaction between aluminum and powdered silica in Ar atmospheres containing metal vapors.

Aluminum is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity.

The reinforcement in AMCs could be in the form of continuous/discontinuous whiskers, whisker or particulates, in volume fractions ranging from a few percent to 70%. Properties of AMCs can be tailored to the demands of different industrial applications by suitable combinations of matrix, reinforcement and processing route. The composites studied in the present work were prepared by infiltration processes where the reinforcements were pressed into a preform that was then infiltrated by the molten Al alloy.



VLS Single Crystal alumina Fibers, produced by Neoker, S.L.

MATERIALS AND METHODS

The short alumina whiskers were processed and pressed into cylindrical fiber preforms. They consist of 20%vol α-Al_2O_3 fabricated by **Neoker,S.L**. with a diameter of 0.5-5 µm and a length of hundreds of micrometers. The main fact about sizes is that the "aspect ratio" is very high and that is proportional to their reinforcing capacity.

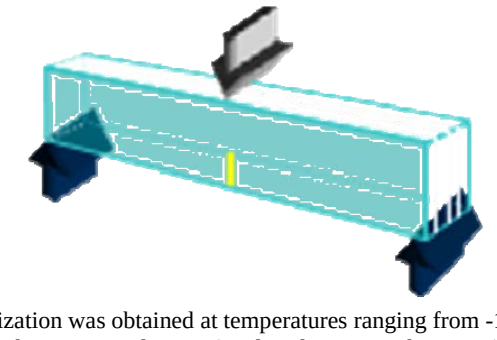
Neoker fibers are composed only by pure alumina and there are no secondary phases. C-axis pure single crystal alumina whiskers, with a white “cotton-like” appearance are deposited by vapor-liquid-solid deposition process. C-Axis growth it’s a quite technical but extremely important characteristic that allow avoiding a lot of problems related to creep and fatigue at high temperature.

The alumina whiskers preforms were obtained as cylinders with a diameter of 16 mm and length of 45 mm using a manual press. They were afterwards heated at 1650 ºC for 2 h.

The final Al composite were obtained by infiltrating the fiber preforms with molten aluminum at the University of Alicante. The infiltration was developed with gas at 675ºC and at 40 Bar.

Cylindrical Preforms made out of Neoker Alumina fibers.

Three Point Bending Flexure Tests have been carried out on 1.5*1.5*15 mm parallelepipeds, machined from the cylindrical Al-based composites obtained in Step 1 (support span was 12 mm for flexural tests, and 8 mm for K_{IC} toughness tests)



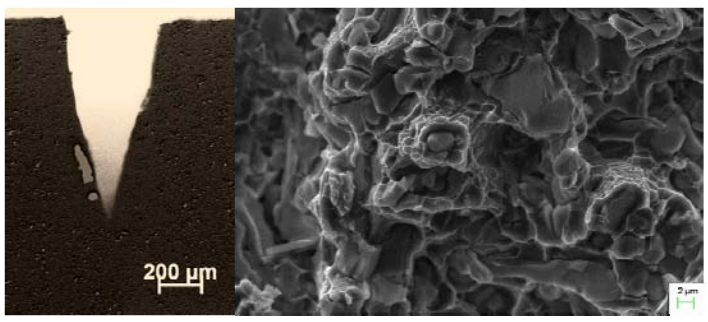
Mechanical characterization was obtained at temperatures ranging from -196 to 500 ºC.

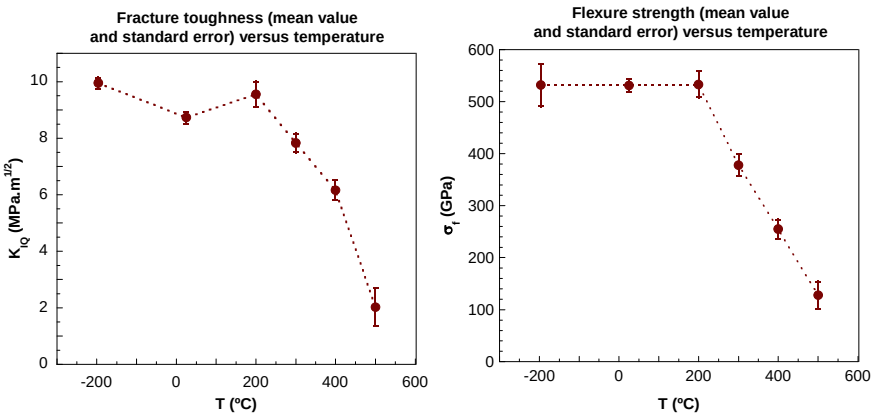
On each sample, a notch was created using Single Edge V-Notch Beam (SEVNB) method, with a notch radius of 3-5 microns and a length of 400 microns (see figure above).

MECHANICAL BEHAVIOUR

As can be seen from the below images, K_{IC} can be considered constant between -196 ºC to 200 ºC, with the composite showing in all cases linear elastic behavior until fracture.

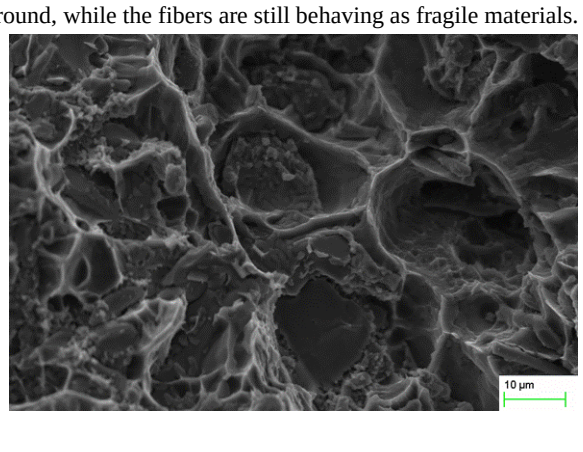
From 300 ºC the apparent fracture toughness of the composite starts to degrade due to the apparition of plastic phenomena that reduce the overall mechanical performance of the matrix. At higher temperatures, K_{IC} is steadily diminishing, and at 500 ºC it can be considered negligible. The effect of the fiber reinforcement is very interesting form 300 ºC to 400 ºC, causing the composite to maintain higher mechanical performance even at temperatures when the aluminum becomes softened due to plastic behavior. The activation of such plastic deformation is hindered by the introduction of the alumina fibers.

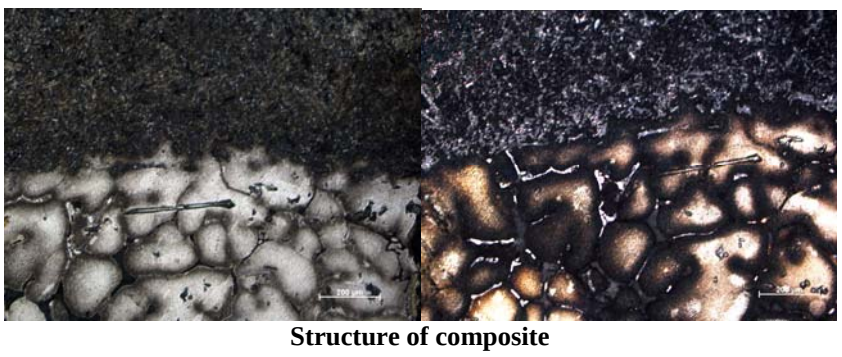




As can be clearly followed from the below images, the matrix is ductile, while fibers fracture in a fragile modus.

As previously stated, the mechanical performance of the material starts to degrade from 300 ºC due to the apparition of plastic processes, but the material still maintains some noticeable performance at 400 ºC. The inter-granular plastic micro-processes at 400 ºC can be clearly seen when fibers are around, while the fibers are still behaving as fragile materials.





Structure of composite

CONCLUSSIONS

- Fibers are randomly oriented, although they are mostly normal to the test direction.
- The mechanical performance is almost constant between -196 to 200 ºC, with the composite showing a linear elastic behavior up to fracture. In this case, the values obtained are comparable to other medium to good quality Al based MMC’s, due to the presence of the Al fiber as reinforcements.
- From 300 ºC the mechanical performance starts to degrade, but with Neoker fibers, the composite is still able to maintain a good performance.
- The grain size of the aluminum is greatly diminished due to the presence of fibers.
- As soon as the processing parameters will be improved, it is expected to obtain outstanding performance in the reinforced aluminum, showing that Neoker fibers are a very promising material for high added-value applications, specially where creep and fatigue at high temperatures represent an issue to solve.